UNIVERSITY OF SWAZILAND

FINAL EXAMINATION 2007/08

TITLE OF PAPER: INTRODUCTORY CHEMISTRY I

COURSE NUMBER: C111

TIME: THREE (3) HOURS

INSTRUCTIONS:

There are **six** questions. Each question is worth 25 marks. Answer **any four** questions.

Non-programmable electronic calculators may be used.

DO NOT OPEN THIS PAPER UNTIL PERMISSION TO DO SO HAS BEEN GRANTED BY THE CHIEF INVIGILATOR.

Question 1 (25marks)

a) Oxygen gas can be generated by heating potassium chlorate:

$$2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)$$

What volume of oxygen gas, collected by displacement of water and measured at 70.0 °C and 735.0 Torr will be formed by the decomposition of 13.5 g potassium chlorate? [5]

b) The density of air at 760.0 Torr and 25.0 °C is 1.186 g/L.

(i) Calculate the average molar mass of air.

(ii) From this value and assuming that air contains only molecular nitrogen and molecular oxygen gases, calculate the mass % of N_2 and O_2. [8]

c) Arsenic (III) sulphide sublimes readily, even below its melting point of 320 °C. The molecules of the vapour are found to effuse through a tiny hole at 0.28 times the rate of effusion of Ar atoms under the same conditions of temperature and pressure. What is the molecular formula of arsenic(III) sulphide in the gas phase? [6]

d) A mixture containing 0.538 mol He(g), 0.315 mol Ne(g) and 0.103 mol Ar(g) is confined in a 7.00 L vessel at 25 °C.

(i) Calculate the partial pressure of each of the gases in the mixture.

(ii) Calculate the total pressure in the mixture. [6]

Question 2 (25marks)

a) Metal chlorides, such as praseodymium chloride, $PrCl_3$, can be prepared by heating praseodymium oxide, Pr_2O_3, with ammonium chloride to yield the chloride, $PrCl_3$, plus water and ammonia.

(i) Write a balanced equation for the reaction.

(ii) If 50.0 g Pr_2O_3 is used, what mass of $PrCl_3$ will be produced? [7]

b) An excess of silver nitrate solution is added to 50.0 mL of hydrochloric acid of unknown concentration. The following reaction takes place:

$$AgNO_3(aq) + HCl(aq) \rightarrow AgCl(s) + HNO_3(aq)$$

The precipitate, silver chloride, is isolated, dried and found to weigh 0.658 g. What is the molarity of the hydrochloric acid solution? [6]

c) Antimony reacts with oxygen as follows

$$4\ Sb(s) + 3\ O_2(g) \rightarrow 2\ Sb_2O_3(s)$$

(i) What type of reaction is this?

(ii) What is the limiting reactant when 5.0 mol Sb(s) and 5.0 mol $O_2(g)$ react?

(iii) How many moles of the excess reactant remain if reaction is complete?

(iv) How many moles of product can be formed?

(v) If 2.0 mol Sb_2O_3 forms, what is the percentage yield? [12]

Question 3 (25marks)

a) A photon of light has an energy of 95.0 kJ/mol.
   (i) What is the wavelength of this light?
   (ii) What is its frequency? [5]

b) What does the Pauli Exclusion Principle say about the possible values of the four quantum numbers? [2]

c) For krypton in its ground state, indicate how many electrons have each of the following quantum number values.
   (i) $n = 3$ (ii) $l = 1$ (iii) $m_l = -1$ (iv) $n=3\ l = 2$
   (v) $l = 0\ m_s = ½$ (vi) $n= 4, l = 1\ m_l = 1$ [7]

d) Calculate the wavelength of an electron that has mass 9.11×10^{-28} g and is travelling at 5.05×10^{6} m/s. [3]

e) Write the electron configuration of the following species:
   (i) Mn (ii) Ni^{2+} (iii) S^{2-} (iv) Ca [8]

Question 4 (25marks)

a) Arrange the following species in order of increasing size. In each case give a brief explanation:
   (i) Ar, Ca, K, Sc
   (ii) Sc^{3+}, Y^{3+}, La^{3+}
   (iii) Br^-, Cl^-, N^{3-}, P^{3-}, S^{2-}. [6]

b) Which member of each pair should have the largest first ionization energy? Explain briefly.
   (i) S or Cl (ii) K or Rb (iii) Ne or O [6]

c) The second electron affinity is always positive and is always more positive than the first electron affinity. Explain this observation. [3]

d) Which of the following elements should have chemical properties similar to those of oxygen N, F, S, C, Se? Justify your answer. [3]

f) Name two ions that could have the electron configuration
   (i) $1s^2 2s^2 2p^6 3s^2 3p^6$
   (ii) $[Ar]4s^0 3d^2$ [4]

g) Why is the aluminium ion smaller than the aluminium atom? [3]

Question 5 (25 marks)

a) Write thermochemical equations that correspond to the following statements:

(i) The standard enthalpy of combustion of liquid benzene, C_6H_6, is -3268 kJ/mol.

(ii) The standard enthalpy of fusion of water is +6.01 kJ/mol

(iii) The standard enthalpy of formation of nitrogen dioxide gas is +33.18 kJ/mol. [5]

b) Calculate the enthalpy change for the reaction

$$4HCl(g) + O_2(g) \rightarrow 2Cl_2(g) + 2H_2O(l) \quad \Delta H^o = ?$$

Use the following data:

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g) \qquad \Delta H^o = -184.6 \text{ kJ}$$
$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l) \qquad \Delta H^o = -571.7 \text{ kJ}$$ [5]

c) Consider the reaction

$$H_2(g) + I_2(g) \rightarrow 2\,HI(g) \qquad \Delta H = 51.88 \text{ kJ}$$

What is the enthalpy change if 155 g of HI(g) is produced with appropriate amounts of reactants? [4]

d) Consider the following reaction

$$MgO(s) + H_2O(l) \rightarrow Mg(OH)_2(s) \quad \Delta H = -37.7 \text{ kJ}$$

Suppose this reaction is carried out in a calorimeter containing 1250 g of water initially at 25 °C. The calorimeter has a heat capacity of 110.5 J/°C and the specific heat capacity of water is 4.184 J g^{-1} $°C^{-1}$. If 80.0 g of magnesium oxide is added to the water and it reacts completely, what is the final temperature? [7]

e) Very pure silicon used in semiconductors can be prepared by the reduction of silicon tetrachloride with sodium metal:

$$SiCl_4(l) + 4Na(s) \rightarrow 4\,NaCl(s)\ Si(s)$$

Given that the enthalpies of formation of $SiCl_4(l)$ and NaCl(s) at 25 °C are -687.0 kJ/mol and -411.1 kJ/mol respectively, calculate the stand enthalpy change of this reaction at 25 °C. [4]

Question 6 (25 marks)

a) Consider the following reactions:

$$CaCl_2(aq) + Na_2SO_4(aq) \rightarrow CaSO_4(s) + NaCl(aq)$$

$$HBrO_3(aq) + Ba(OH)_2(aq) \rightarrow Ba(BrO_3)_2(aq) + H_2O(l)$$

$$KI(aq) + Cl_2(g) \rightarrow KCl(aq) + I_2(aq)$$

(i) Balance each equation
(ii) Classify each reaction as precipitation reaction, acid-base neutralization or redox reaction.
(iii) If the reaction is a precipitation, write the net ionic equation, if acid-base, identify the acid and the base and if it is a redox reaction identify the oxidizing and reducing agents. [12]

b) Copy the following table and fill in the gaps [5]

Symbol	$^{39}Co^{3+}$			
Protons		34	76	80
Neutrons		46	116	120
Electrons		36		78
Net Charge			2+	

c) Give the name or chemical formula, as appropriate for the following compounds

(i) iron(III) carbonate (ii) $HIO_3(aq)$ (iii) nitrous acid

(iv) Zinc nitrate (v) IF_5 (vi) XeO_3

(vii) Tetra phosphorus hexasulphide (viii) $CrCl_3$ [8]

THE END

General data and fundamental constants

Quantity	Symbol	Value
Speed of light	c	$2.997\ 924\ 58 \times 10^{8}$ m s^{-1}
Elementary charge	e	$1.602\ 177 \times 10^{-19}$ C
Faraday constant	$F = N_A e$	9.6485×10^{4} C mol^{-1}
Boltzmann constant	k	$1.380\ 66 \times 10^{-23}$ J K^{-1}
Gas constant	$R = N_A k$	8.314 51 J K^{-1} mol^{-1}
		$8.205\ 78 \times 10^{-2}$ dm^3 atm K^{-1} mol^{-1}
		6.2364×10 L Torr K^{-1} mol^{-1}
Planck constant	h	$6.626\ 08 \times 10^{-34}$ J s
	$\hbar = h/2\pi$	$1.054\ 57 \times 10^{-34}$ J s
Avogadro constant	N_A	$6.022\ 14 \times 10^{23}$ mol^{-1}
Atomic mass unit	u	$1.660\ 54 \times 10^{-27}$ Kg
Mass		
electron	m_e	$9.109\ 39 \times 10^{-31}$ Kg
proton	m_p	$1.672\ 62 \times 10^{-27}$ Kg
neutron	m_n	$1.674\ 93 \times 10^{-27}$ Kg
Vacuum permittivity	$\varepsilon_o = 1/c^2\mu_o$	$8.854\ 19 \times 10^{-12}$ J^{-1} C^2 m^{-1}
	$4\pi\varepsilon_o$	$1.112\ 65 \times 10^{-10}$ J^{-1} C^2 m^{-1}
Vacuum permeability	μ_o	$4\pi \times 10^{-7}$ J s^2 C^{-2} m^{-1}
		$4\pi \times 10^{-7}$ T^2 J^{-1} m^3
Magneton		
Bohr	$\mu_B = e\hbar/2m_e$	$9.274\ 02 \times 10^{-24}$ J T^{-1}
nuclear	$\mu_N = e\hbar/2m_p$	$5.050\ 79 \times 10^{-27}$ J T^{-1}
g value	g_e	2.002 32
Bohr radius	$a_o = 4\pi\varepsilon_o\hbar/m_e e^2$	$5.291\ 77 \times 10^{-11}$ m
Fine-structure constant	$\alpha = \mu_o e^2 c/2h$	$7.297\ 35 \times 10^{-3}$
Rydberg constant	$R_\infty = m_e e^4/8h^3 c\varepsilon_o^2$	$1.097\ 37 \times 10^{7}$ m^{-1}
Standard acceleration of free fall	g	9.806 65 m s^{-2}
Gravitational constant	G	$6.672\ 59 \times 10^{-11}$ N m^2 Kg^{-2}

Conversion factors

1 cal	=	4.184 joules (J)	1 erg	=	1×10^{-7} J
1 eV	=	$1.602\ 2 \times 10^{-19}$ J	1 eV/molecule	=	96 485 kJ mol^{-1}

Prefixes

f	p	n	μ	m	c	d	k	M	G
femto	pico	nano	micro	milli	centi	deci	kilo	mega	giga
10^{-15}	10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{-1}	10^{3}	10^{6}	10^{9}

PERIODIC TABLE OF ELEMENTS

GROUPS

PERIODS	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1.008 H 1																	4.003 He 2
2	6.941 Li 3	9.012 Be 4											10.811 B 5	12.011 C 6	14.007 N 7	15.999 O 8	18.998 F 9	20.180 Ne 10
3	22.990 Na 11	24.305 Mg 12											26.982 Al 13	28.086 Si 14	30.974 P 15	32.06 S 16	35.453 Cl 17	39.948 Ar 18
4	39.098 K 19	40.078 Ca 20	44.956 Sc 21	47.88 Ti 22	50.942 V 23	51.996 Cr 24	54.938 Mn 25	55.847 Fe 26	58.933 Co 27	58.69 Ni 28	63.546 Cu 29	65.39 Zn 30	69.723 Ga 31	72.61 Ge 32	74.922 As 33	78.96 Se 34	79.904 Br 35	83.80 Kr 36
5	85.468 Rb 37	87.62 Sr 38	88.906 Y 39	91.224 Zr 40	92.906 Nb 41	95.94 Mo 42	98.907 Tc 43	101.07 Ru 44	102.91 Rh 45	106.42 Pd 46	107.87 Ag 47	112.41 Cd 48	114.82 In 49	118.71 Sn 50	121.75 Sb 51	127.60 Te 52	126.90 I 53	131.29 Xe 54
6	132.91 Cs 55	137.33 Ba 56	138.91 *La 57	178.49 Hf 72	180.95 Ta 73	183.85 W 74	186.21 Re 75	190.2 Os 76	192.22 Ir 77	195.08 Pt 78	196.97 Au 79	200.59 Hg 80	204.38 Tl 81	207.2 Pb 82	208.98 Bi 83	(209) Po 84	(210) At 85	(222) Rn 86
7	223 Fr 87	226.03 Ra 88	(227) **Ac 89	(261) Rf 104	(262) Ha 105	(263) Unh 106	(262) Uns 107	(265) Uno 108	(266) Une 109	(267) Uun 110								

Atomic mass → 10.811
Symbol → B
Atomic No. → 5

TRANSITION ELEMENTS

*Lanthanide Series	140.12 Ce 58	140.91 Pr 59	144.24 Nd 60	(145) Pm 61	150.36 Sm 62	151.96 Eu 63	157.25 Gd 64	158.93 Tb 65	162.50 Dy 66	164.93 Ho 67	167.26 Er 68	168.93 Tm 69	173.04 Yb 70	174.97 Lu 71
**Actinide Series	232.04 Th 90	231.04 Pa 91	238.03 U 92	237.05 Np 93	(244) Pu 94	(243) Am 95	(247) Cm 96	(247) Bk 97	(251) Cf 98	(252) Es 99	(257) Fm 100	(258) Md 101	(259) No 102	(260) Lr 103

( ) indicates the mass number of the isotope with the longest half-life.